



Select Committee on the European Union

Internal Market Sub-Committee

Corrected oral evidence—Brexit: space

Thursday 6 June 2019

10.10 am

Watch the meeting

Members present: Lord Whitty (The Chairman); Lord Aberdare; Baroness Donaghy; Lord German; Baroness McGregor-Smith; Baroness Randerson; Lord Rees of Ludlow; Lord Robathan; Lord Russell of Liverpool; Lord Wigley.

Evidence Session No. 1

Heard in Public

Questions 1 - 9

Witnesses

[I](#): Dr Jamie Morin, Vice-President, Defense Systems Operations, The Aerospace Corporation; Gina Galasso, Managing Director, Vaeros Ltd; Robert Samuel Wilson, Policy Analyst, Center for Space Policy and Strategy.

Examination of witnesses

Dr Jamie Morin, Gina Galasso and Robert Samuel Wilson.

Q20 The Chairman: Good morning and welcome. You will know that the Committee has been interested at various points in the situation of the UK space sector, in view of Brexit—particularly in view of the exclusion from most of the parts of Galileo—and in what the future holds for what we hope will be a positive and technology-leading sector. We thought it would be useful to have an outside view of how you see the British space sector, its future relations with America, Europe and anywhere else, and its strengths and weaknesses.

Could we kick off with each of you saying a bit about your background, your organisation, how you have come to this point, and why you produced this interesting report, which provoked us to invite you here today? This is a public session, which is being recorded and broadcast, so do not say anything that you would not want to be seen in public, although it probably will not.

Dr Jamie Morin: I have the privilege of running the Center for Space Policy and Strategy at the Aerospace Corporation. I recognise that the Aerospace Corporation and the role of the federally funded research and development centres in the United States are foreign for the rest of the world, so I will take a moment to explain what that means and why we have it.

It was created in 1960, by the US Air Force, as an independent, non-profit organisation to provide it with technical advice on its space programmes. Initially these were missile programmes and then a whole host of satellite programmes. We have expanded from there to support NASA's activity and the US intelligence community. We were created because the US Government realised that they did not have the necessary internal technical expertise to make smart decisions on the direction to go in in space that were independent and free from conflicts of interest. The Government were also at a disadvantage when it came to technical expertise for monitoring the work of the for-profit contractors, which are such an important part of the aerospace industry around the world.

That is why we were created, and we remain in that role. The Center for Space Policy and Strategy is part of the Aerospace Corporation, which was created by the US Government, which gives rise to the question why it would write on the issue of Brexit. It is because the US Government have taken a very serious and focused role in international partnership as a key aspect of space strategy. Some years ago, they gave clearance for Aerospace to engage more broadly internationally, in particular with key allies such as the United Kingdom. In 2015, we created a UK subsidiary to help support some of that partnership activity in an independent way. That has resulted in us increasing the depth of our study and engagement with the UK across the space sector.

My colleague to my left, Gina Galasso, is the executive director of our UK subsidiary, Vaeros. My colleague to her left, Sam Wilson, is one of our researchers at the Center for Space Policy and Strategy. He came to us from the US Government Accountability Office, the equivalent to the National Audit Office here. He has also been a great member of our team. We wrote the report because it is a major moving piece in the firmament of international space collaboration. We felt that there was poor understanding, in the US and around the world, of everything involved in the key decisions facing the UK.

As I think the Committee has learned through the testimony it has taken, there are varying views on the implications and strategic choices facing the UK. We are a non-advocate and we do not seek to push any particular policy. We seek to crystallise the choices that face government, US or otherwise. I was shocked that this report has been one of the most popular and widely read documents we have produced since the reinvigoration of our centre about two and a half years ago. We have received numerous media inquiries about it, and comments from various members of the UK Government and senior US government officials, as well as academics and others. We appear to have hit a nerve, and we are grateful for the opportunity to share thoughts with the Committee.

The Chairman: Thank you very much for that. Do either of your colleagues want to add anything?

Gina Galasso: I will provide a bit of background about myself and my views and my motivation for this. I have been with the Aerospace Corporation for a long time—over 30 years. In that time, I have also had the opportunity to work in Europe as NOAA's¹ envoy at EUMETSAT². I was able to have some exposure and insight into how Europe works and the relationship between the US and Europeans. That was very informative.

Coming back to aerospace, as Jamie has pointed out, with a lot of things in the US pointing towards more collaboration with the allies we decided to start up a UK subsidiary. Given my experience, I was put in place to work there. One of the motivations for this is that, having spent a lot of time with industry and government in the UK, it was clear that there was a need to take a step back and put forward some of the things that have been presented, to project a clearer picture of what is going on with Brexit than has been put out publicly.

Robert Samuel Wilson: I have nothing to add. Those were comprehensive introductions.

Dr Jamie Morin: This paper is really Gina's baby. She conceptualised it and helped to frame it in a very nice way.

The Chairman: Okay. Who would you expect it to influence? Is it primarily an information paper for the American Government and

¹ National Oceanic and Atmospheric Administration

² European Organisation for the Exploitation of Meteorological Satellites

American industry, or were you expecting to influence European and British actors as well?

Dr Jamie Morin: I would say that we were deliberately global. That has been borne out by the web accesses to the paper. About half of them have come from the US, 30% from the UK and 20% from continental Europe.

The Chairman: Right. That is impressive. Baroness McGregor-Smith recently attended the European space conference on the Committee's behalf.

Q21 **Baroness McGregor-Smith:** Thank you for your paper. I found it really interesting and helpful, particularly after I visited Brussels in January.

Do you think the UK should prioritise having a close relationship and co-operation with the Europeans, or should we strengthen our ties with the US or China?

Dr Jamie Morin: I will come at this from a bit of a biased perspective.

Baroness McGregor-Smith: Of course. We would expect you to do that.

Dr Jamie Morin: In my career in and out of government I have placed a lot of emphasis on deepening the US-UK partnership. When I was working at the US Department of Defense I had multiple British exchange officers working under me, both in the US Air Force and when I worked for the Secretary of Defense. I believe strongly in the collaboration. It is not a zero-sum situation, of course. The US collaborates in space with the European Space Agency, with the Russians and partners around the world, particularly in civil space. National security space collaboration is deep and deepening, albeit with a smaller set of partners. It need not be zero-sum or a black and white choice, but there is a great opportunity for collaboration between the US and the UK.

Sam and I had the opportunity to talk informally with the administrator of NASA due to a happenstance intersection at an airport last week. We talked explicitly about this issue. He was not speaking on the record, but he instantaneously off the top of his head had three or four ideas for deepening US-UK collaboration.

There is great opportunity there. The depth of the integration between the EU 27 and UK space sectors is pretty tight. It will perhaps become less deep in the future, but that change will take time. As a former economist, I can say that heavy transaction costs are associated with those kinds of industrial shift.

Baroness McGregor-Smith: You have talked about the opportunities; what immediate risks do you see for Britain post Brexit?

Dr Jamie Morin: To space collaboration?

Baroness McGregor-Smith: Yes.

Dr Jamie Morin: I think this Committee has done a fair bit of investigation into that area; you of course have done some work on the Galileo programme and GNSS.³ The Government here are still struggling with that and analysing alternatives. I understand that a lot of work is under way. If I were to lay things out on a spectrum, I would draw a line from national security collaboration as the most challenged through to highly technical scientific collaboration as probably the least challenged.

The interplay between the European Space Agency, the European Commission and the EU project is complex. There are financial flows and commitments; each is unique in certain ways. As with many other things associated with the withdrawal of the UK from the Union, the devil will be in the details.

The Chairman: Are there any particular technological areas that you think we should prioritise in Anglo-American co-operation? Is there a synergy that could be built on?

Dr Jamie Morin: I will let my colleagues jump in here with specific ideas. Across the mission areas where we rely on space, I would look at national security areas and civil areas, and the major area that overlaps between the two, which is the PNT—positioning, navigation and timing—or GNSS area. That is sort of in the middle.

On the national security side, the UK is looking at major acquisitions in military satellite communication or, in this case, potential procurement of service for military satellite communication. There are substantial opportunities for collaboration in that area. In the US, the air force's Space and Missile Systems Center has set up a team dedicated explicitly to deepening international partnership with a focus on the communications area but also open to multiple other areas in the national security space.

PNT—positioning, navigation and timing—is a fascinating area where there are four major systems that aim at global provision of coverage, all of which are essentially provided to one degree or another as a public good that is available to all but that also have value-added products, such as the PRS for Galileo, that are available on more limited terms to specific members.

It is open to the UK to explore options with the US for deeper involvement in the GPS programme and its military-specific capabilities. Negotiating access post exit to Galileo's PRS is still not out of the question, although I understand that the Government have had a negotiating position on that topic.

On the scientific side, I think the door is open broadly. Most of those programmes are now expressly international in character. Gina, would you like to add any more?

³ Global Navigation Satellite System

Gina Galasso: One thing recently announced is the co-operation and collaboration between the US and the UK in regard to space weather. That has been a long-standing mission area for co-operation. I would imagine that in those civil missions the collaboration would continue and probably increase.

Lord Robathan: On the defence and security implications, in discussions more than a decade ago about Galileo being set up, one issue, particularly for the continent, was the fear of being entirely dependent on the US in defence terms; they wanted an independent system.

One of my great concerns is how secure these systems are, because of taking down the satellites or whatever. You may have a bias in this as well, but do you think from what you have seen that Galileo will be as secure as the US system, especially if we leave Galileo and go more in your slipstream? That was the real issue behind setting it up—the Galileo part.

Dr Jamie Morin: I would respectfully decline to opine on the relative security of the two systems. I am conscious, from having worked on the classified side, of both the strengths and the vulnerabilities of the US system, but I do not have equivalent knowledge of those of the Galileo protected signals. I am in the position that as an analyst I am always anxious about, which is that I have a great deal of information on one of the choices and only a modest amount on the other, which often leads to poor judgment.

Lord Robathan: Okay, it is perhaps an unfortunate question. Let me put it a different way. From a British point of view, if we leave the Galileo security system should we be entirely confident in the security of the US system?

Dr Jamie Morin: No, you should never be totally confident in the security of any IT-based system.

My final job in the Department of Defense was resource allocation for the department as a whole—the long-term resource plan—and then analytic support to the Secretary of Defense in making those choices. For national security, it is about balancing risks. Again, there is no perfect security for anything.

This is particularly true for any system that touches the cyber environment. The US is making large and important investments in the security of the GPS signal and has announced a series of enhancements there. It is working on fielding robust user equipment that will reject efforts to jam or spoof those signals, but perfection in protecting a signal that is broadcast from space is not achievable.

The question is: in the circumstances where you need to rely on it, and can reasonably rely on it, will it be there? Of all the GNSS systems globally, the US GPS system is, I believe, the best protected, but it is not perfect.

The Chairman: I call on Lord Rees, who has a long history in this area, to ask the next question.

Q22 **Lord Rees of Ludlow:** Thank you very much for this interesting report. Most of our concerns are of course about Galileo, which is very special because of the security implications and because, although it involves ESA, there is special funding from the EU, which gives rise to some of the funding and security issues.

I would like to defocus from that for a moment—we will come back to it later—and ask more generally about your perceptions of the UK's collaboration with ESA, et cetera. Perhaps I could venture one comment. You are quite rightly rather critical of the UK Space Agency, but we have to accept that it has never been intended to be anything like a counterpart of NASA; it is just an administrative thing that links the two departments and UKRI.

We have other ways of getting technical expertise. I would like to get your impression of ESA in areas away from Galileo and of the collaboration that we are involved in in those areas.

Dr Jamie Morin: Are you talking about things like Copernicus and other major ESA programmes or the fundamental science?

Lord Rees of Ludlow: Yes. Copernicus is also a special programme which has some EU funding, but I have in mind the general science collaboration. Of course, most of our science is done through ESA now.

Dr Jamie Morin: Yes. I want to clarify one thing. I do not believe that our report is critical of the UK Space Agency. It is a question of being fit for purpose when the purpose may be changing. It is management through change and investment in capabilities. If it is Her Majesty's Government's determination that they will move the agency from a regulatory and industrial promotion-oriented body to an acquisition one, the human capital needed in investment and technical capabilities is real and will take time. It is important to make it clear that that is different from criticising the effort.

Lord Rees of Ludlow: The expertise already exists in the STFC⁴ and other bodies.

Dr Jamie Morin: Yes, and it is a question of scale. If the nation made a determination to embark on a major space acquisition programme, it is not clear to me that there is sufficient expertise across all arms of the Government at present to manage that.

We have a comparison in the paper between the size of the global positioning programme office in the US Air Force's Space and Missile Systems Center to staff the UK Space Agency as a whole. Admittedly that is not a completely fair comparison, and the goals of a UK GNSS system would be different from those of the US GPS, but managing a multi-billion

⁴ Science and Technology Facilities Council

pound acquisition programme is a serious matter and would require some investment in increased government and industry capabilities.

Robert Samuel Wilson: I have one point about the comparison between our GPS acquisition side versus the entire UK Space Agency. In the US, the GPS directorate of the Department of Defense acquisition office for developing and procuring GPS satellites comprises over 500 people. Again, there is a point about scale.

Dr Jamie Morin: A very large share—well over half—of the UK Space Agency's resources now go into ESA programmes, both the optional and mandatory basic science ones. As a former resource allocator—I no longer have responsibility for those sorts of things—my perspective is that if resources are not limited, doing all the above would be terrific.

It will not shock you that as head of the Center for Space Policy and Strategy I feel that the nations of the world underinvest somewhat in space. However, resources are not unlimited, and there would be real trade-offs for science if the UK chose to invest heavily in the acquisition of a large satellite constellation.

Lord Rees of Ludlow: The ESA science programme is thought to be very successful. For non-planetary stuff, and even planetary stuff, it has been fully equal to NASA in the last 10 years. I have to say that the US is thought to be a poor collaborator, because it can never commit its budget more than a year ahead. There were famous cases, such as Ulysses, where America dropped out, to the great annoyance of Europe. That has made us very cautious about having the Americans as major collaborators in any of our big European projects in civilian space science. Do you have any comment on that?

Dr Jamie Morin: There are those who believe that the strategic policy of both the UK and United States is to annoy Europe. I cannot, of course—

Lord Robathan: You could say vice versa.

Gina Galasso: Yes. That was exactly one of the challenges that EUMETSAT had when I was there. It was partnering with the US, which was going to contribute instruments. A lot of times the schedule was not kept to because the US had an annual budget.

Lord Rees of Ludlow: It is important to emphasise that we are happy with ESA. All our space science—Copernicus, et cetera—will, we hope, continue, irrespective of Brexit.

The Chairman: Constraint on resources is primarily related to government-financed institutions. What about the American space sector and its propensity to look at post-Brexit Britain for investment opportunities? Is there scope there?

Dr Jamie Morin: We are seeing, as I think you are aware, Lord Chairman, an enormous amount of energy and excitement in the privately financed realm of US space. For the past four or five years,

there has been a rapid ramping up of venture capital and other forms of equity investment in the space sector. It is not clear how long that will continue; many of the investments that are being made right now are in pre-profitability companies. That should not be a surprise; the space sector requires a high degree of capital expenditure before you can earn revenue.

The barriers to entry have come down dramatically, though. The UK has been a major part of this, with the significant leadership role that you take in the small-satellite sector. It is simply the case that much more can be done with small satellites today than could be done one or two decades ago—more relevant missions, economically and for national security.

The US Government are still working their way through the opportunities opened up for scientific, national security and commercial missions, and are re-looking at decisions on the areas where it is necessary for them to develop capabilities *de novo*, where they can buy capabilities that are already extant in private industry but own them as the Government, and where they can simply purchase services.

We do all of those things already in space. Even the military relies heavily on commercial satellite communications. However, we see a trend under way of more resources shifting to buying services and already developed commercial technology, and resources coming out of the *de novo* government development of systems.

Lord Rees of Ludlow: On the small-satellites point, you already have Planet Labs and the array of environmental satellites with pretty good resolution. There is talk now from SpaceX and Google of huge arrays of satellites to bring the internet to Africa. Are there any security implications with these?

Dr Jamie Morin: Yes. In the past couple of years, my institute has published about 50 papers, a large share of which address exactly those topics. We are calling it the democratisation of space. We have a whole series related to that, and one to the increased crowding. From the perspective of space-traffic management and other issues, these developments, while exciting, come with new challenges. That has been the focus of the bulk of our research over the past two to two and a half years.

Lord Rees of Ludlow: What is the scope for international partnership in those?

Dr Jamie Morin: The commercial efforts are, almost without exception, international. The sources of finance for these companies are global. The technology involved is global. The human capital is flowing globally. The share of resources in space is shifting from extraordinarily government-dominated to slightly more balanced. It is still government-dominated, but the private sector is a larger minority now.

One of the consequences of that shift is that the typical government restrictions on, say, participation of foreign nationals, strict attention to the supply chain and the country of origin of components are not there to nearly the same extent in commercial ventures. In some cases, that is a challenge for the Government as a customer. Do they have enough confidence in a system to procure it for state purposes? As in so many other areas, the lowering of barriers to trade and flow internationally offers opportunities to reduce cost and improve service.

Q23 Lord German: Picking up on your initial remark about your job being to crystallise the choices rather than to opine, or make opinion, I will try to push a little more on the section relating to the Government's decision to replace Galileo with their own global navigation satellite system and all that comes with that.

In your report, you quote experts, particularly one expert, who say that the UK should look strategically at what it wants to do on its own, what it wants to do in collaboration with others and what it wants to buy from others. It is basically those three choices.

I cannot tell which side of this argument you have come down on: whether you are saying, yes, the UK Government are reacting to the Europeans' decision, so Galileo has to be replaced and we have to have our own, or whether we should follow the route of those three strategic choices.

Could you enlighten us as to your assessment of the opinions which you have expressed in the paper but where you have yet not come down on one side or the other?

Dr Jamie Morin: I have some training as an economist, and you know the joke that you should never hire a two-armed economist because they will always tell you, "On the one hand and on the other hand". Again, we strive to be non-advocate.

Let me talk more generally about how I would think this through from a strategic resources allocation and strategy selection perspective. The bulk of my training is from the defence side. In the military, one thinks about strategy in terms of ends, ways and means. What is the end state that you are looking to attain? What ways, material and capabilities do you have to attain those ends? And what is your approach; what means do you adopt?

The fundamental question facing the UK as I see it, in a world where the UK is somewhat more distant from the EU, is the extent to which national sovereignty demands independent capabilities: that is, fully independent from any other nation.

The answer will vary from capability area to capability area. Nations with nuclear weapons typically seek maximum independence in the command and control of those weapons, because, having invested in that capability as an ultimate national guarantee, to then be dependent on another nation for the ability to control those seems unsatisfactory.

On the other hand, almost no nation invests in a global communications architecture that is completely independent for large-scale, wideband communications. We rely on a network of commercial providers and limited government. Even nations such as the US and China are interdependent with others in the global market in those areas.

In a perfect world, would advocates of national security want those things to be completely sovereign? Sure, but nobody's budget is unlimited; they are making choices. So the question with something like GNSS is where it falls on that spectrum. What future scenario is the UK most concerned about? Is it a modestly likely scenario—likely enough to enter into the realm of possibility—that you are working to hedge against, and how much is it worth to hedge against?

Is an environment with a US positioning, navigation and timing system, a European system, a Russian system, a Chinese system and national augmentation systems from Japan and other nations an area where you are willing to free-ride completely? Or is it an area where you would like to have a modest overlay that gives you minimal capability independently, maybe locally or across a defined area of operations? Or is it an area where you want to invest several billion pounds in a fully independent capability? That is a decision for the UK to make; it is not for me to make.

Lord German: Well, yes and no, because you are basically telling which approach you think is the right one to take.

Let me pose the question the other way round. The UK has said that we will have our own Galileo system. Does that not in fact answer the questions that you have just raised in the way that you would approach it? As a kind of approach to the problem, has the UK not taken the view that you expressed when you said: "What do you want to share? What do you need individually? What do you want to augment from other people? What do you want to buy in?" That seems to be the approach that you are suggesting is the right one. What have the UK Government done so far that meets that approach? It seems to me that they have not done that.

Dr Jamie Morin: I am not party to the internal deliberations of either the Ministry of Defence, the space agency, the Prime Minister or the Cabinet Office, so it is hard for me to opine on the unexpressed strategic framework. I would leave that to the Committee and to the Government here.

Lord German: But do the words "pursuit of a global navigational satellite system", which the British Government have said they will undertake, imply a full-scale type of approach like the Galileo system?

Dr Jamie Morin: I will let Sam expand on this, but we identify in the report what we think are the two critical words in that policy objective. One is "global", the other is "independent".

The alternative to global is regional. A regional positioning, navigation and timing system, or “NSS system,” is achievable, and other nations have pursued it. Notable among them is the Japanese QZSS⁵ system, which has satellites in an orbit designed to maximise coverage and was fundamentally designed to provide a better navigation and positioning service in urban areas with tall buildings, where the look angles to the satellites in the GPS constellation were not good enough to provide a reliable service. The European geosynchronous satellite that augments Galileo is another example of that: it integrates with the global system of Galileo, but it is itself. This is completely technically feasible and an available option that would provide enhanced services to the public, military forces, public safety forces and the like.

That is one key choice. The other is: how independent is independent? Would it be a system that is compatible in wavelength, frequency and characteristics of the signal with one of the existing systems, be it Galileo or GPS? I presume that it would not be BeiDou or GLONASS⁶, but who knows? That is a choice as well. That level of compatibility is another key strategic choice that can drive cost, but again it would provide less sovereign capability in the—admittedly unlikely—future where both Galileo and GPS were denied to the United Kingdom.

The Chairman: This has moved into the area that Baroness Donaghy was going to ask you about.

Q24 Baroness Donaghy: You have talked quite a bit about the pros and cons of developing an independent regional satellite navigation system latching on to existing systems. Of course, we are all trying to read between the lines of government statements as well—what they mean and whether they are just whistling to keep cheerful or determining long-term strategy.

However, the Government have also said that they want a UK system that will provide both open and encrypted signals with the same range of commercial and security applications as Galileo, and they have claimed that they will fund that. If that is the case, that leans more, I suspect, towards an independent regional navigation system. If it is whistling to keep cheerful until they have worked out how much money they are actually going to spend, it would leave open the question of whether we were going to latch on to something else where the work has been done but we did not have the same control over research and development.

Would you like to explore the pros and cons of that a bit more, bearing in mind that some of these government statements may just disappear like so much sand? We do not really know, but we are trying to explore what the advantages and disadvantages would be.

It appears to me that the extent of international co-operation on some of this is quite remarkable. It is almost like in medicine—there is an assumption that people want to exchange information. Obviously, when

⁵ Quasi-Zenith Satellite System

⁶ Globalnaya Navigazionnaya Sputnikovaya Sistema

you get to the level of security, the political walls may come down or sensitivities arise.

Dr Jamie Morin: They certainly do. I will let Sam expound on some of the findings from the interviews and discussions he had in the preparation of the paper, but before I do I just note that, at the top level, we—and by “we” I mean the nations of the world—tend to be a bit scattershot on these things.

There are some circumstances where we put up very high security walls and others where we are in extraordinarily tight collaboration. It often feels as though there is not a lot of rhyme or reason to this; there may be a great deal of inertia. When I was the acting under-secretary of the US Air Force, the space office that reported to me had Australian and UK officers in it. We were essentially reliant on everyone’s good will not to take papers off the printer that were marked “Not for dissemination beyond US nationals”. It was not quite that lax, but because they were all working together on extraordinarily sensitive issues a great deal of mutual good will was required.

Of course, the Five Eyes intelligence relationship over the past many decades involves matters of the utmost importance to the members of that collaboration. Are those issues less sensitive than positioning, navigation and timing? I will leave that to you to judge. We have very deep collaborations in important areas that touch on the heart of national security.

Robert Samuel Wilson: It is a great question, and I will touch on elements from it and from the Lord’s previous question, because they are related.

The August announcement that the UK was going to pursue an alternative system said that it would be “independent” and “global”. This really narrows the choices, and we cover this in the paper. Based on the technical foundation of aerospace, our analysis suggests that at an optimal orbit for position, navigation and timing it should require 30 satellites.

If you delete one of the words “independent” or “global”, your decision space becomes a lot bigger. We touch on just two choices, and this is important. Forgetting about the two words, one option is an independent regional navigation system. Our analysis shows that, if it were independent of other global navigation satellite systems, this would require seven satellites at a higher altitude orbit—geosynchronous or geostationary. India is developing such a system. Or you can have just an augmentation system that is dependent on one of these other global navigation satellite systems. You would have more options for fewer satellites.

Again, those are just two options; the UK has a whole suite of options at its disposal. We were just trying to highlight what some of the options

could be if the words “independent” and “global” are not integral to what system the UK chooses.

Gina Galasso: Thank you very much. That was very good. Sam talked about analysis. We did no analysis of what the UK was looking at as a replacement for Galileo. This is because of all the work that we do for the GPS programme office, working with the Europeans and other nations and helping them to figure out the art of the possible for a navigation system. I just wanted to make it clear that we had not studied the UK global navigation system.

The Chairman: Has anybody?

Gina Galasso: I do not know. We are not privy to that.

The Chairman: We now go back to the subject of Galileo.

Q25 **Lord Russell of Liverpool:** There is a possibility that the UK could apply for access to the PRS element of Galileo—the encrypted area. However, we notice that the United States and Norway are currently negotiating with the EU on access to PRS. We would be very interested in whether you have any insight as to why the US Government have applied for access. Might that inform the UK Government’s approach to doing the same?

Dr Jamie Morin: I do not speak for the US Government in this regard, and I have to be careful to note that I am a—former--government official. You heard my explanation of the unique role that Aerospace plays in advising the US Government.

In GNSS, the general principle is “more is better”. If you are able to access multiple signals and can use them as checks against each other, you have more resiliency. In particular, the US military is very focused on operation in a contested space environment, which could include potential adversaries physically attacking satellites. It could also include jamming or spoofing of signals.

For many years, the US had laws and policies in place that essentially said that US military systems needed to rely solely on GPS and to be capable of using the military code on GPS for resilience. In recent years, there has been an increasing realisation that taking in, and operating with, the other global navigation signals can be a source of more resiliency.

A potential adversary will need to jam or spoof more signals. If they are messing with one and the others are not similarly messed with, that can be an indication that one is being messed with. The risk with your positioning system is that someone is confusing you and you are not aware of it. Once you are aware that they are confusing you, you have other ways of navigating and checking your position.

In general, the US is shifting to a “more is better” approach here. Access to the PRS would be aligned with that. It is a rich signals environment

now. Aerospace has been doing a great deal of research on positioning and navigation relying on non-space signals. It turns out that the radio frequency environment around the globe is rich. There are signals everywhere—everything from television broadcasts, other satellites, radio, wi-fi routers.

There is a unique fingerprint of that signals environment pretty much anywhere on the planet. You can use that to locate yourself quite well if you have gathered the necessary data. We are doing some interesting basic research in that area aimed at providing options should someone mess with the GPS signal. At the same time, of course, we are working to invest in making that signal more robust and better protected.

Lord Russell of Liverpool: So the logic, given what you have said, of the UK considering applying for access would be to spread its bets better in what might be a difficult situation.

Dr Jamie Morin: Yes. Of course, it would depend on the terms of the agreement. My sense is that up to this point the UK Government have discussed PRS in terms of whether it is the primary means of assured access for the UK. That is where industrial access and access to the security decision-making committees are goals. If the UK chooses to rely on a secondary system, or one of several systems, some of those questions perhaps become less heavily weighted.

Q26 **Lord Wigley:** Your paper highlights small-satellite manufacturing as one of the successes of the UK, and that 40% of all small satellites in orbit in 2018 were UK-built, which is quite staggering. Does Brexit, in your view, have any implications for the UK's small satellite industry?

Dr Jamie Morin: The short answer of course is yes.

Lord Wigley: I thought so.

Dr Jamie Morin: It is difficult to make detailed predictions. As with any other hi-tech industry, my sense is that the UK small-satellite industry is dependent on an international flow of talent and capital, so a great deal depends on exactly how the UK withdraws from the Union and what comes after.

Those issues will be decided at a higher level than the space sector—of course, it is just one of many factors. It is in line with what I said earlier about our institute's research on democratised space. Barriers to entry in the satellite manufacturing industry are declining in what used to be a very capital-intensive industry. Due to miniaturisation, the degree of modularity in the designs and the increasing role of semi-off-the-shelf components, it has become easier to create a satellite manufacturing line.

From a UK perspective, it is probably reasonable to be concerned. A lot of the UK's advantage in the small-satellite industry is based on an existing industrial base, and the barriers to that base moving are perhaps declining.

Lord Wigley: Of course, part of that industrial base has included American private companies and corporations locating here as a platform from which to interact with Europe. Do you see that having a negative impact?

Dr Jamie Morin: Again, outside the most sensitive national security programmes, the industry is increasingly globalised. The flow of components and designs has increased dramatically. That trend is exogenous to the UK's decision on "in or out of the Union?" I would expect it to continue, absent a dramatic worsening of the global security environment that leads nations to build higher walls around themselves. From the UK perspective, I would take that trend line as a given and figure out how to build a strategy that responds to it.

Lord Wigley: Could I take that on a little bit? What are the other comparative strengths of the UK in the global market?

Dr Jamie Morin: There is real strength in cryptography and systems associated with it. You have a fairly experienced workforce in satellite ground operations and then a series of component manufacturing areas. I might defer to Gina, who has been more closely in touch with the UK industry over a multi-year period.

Gina Galasso: Thank you, Jamie. One of the biggest strengths of the UK is in instrumentation. That is one of the areas where you have contributed quite a bit to the ESA programmes. If you are asking whether that is an area that you should continue to grow and invest in, the answer is yes.

A lot of the innovation early on in Galileo came from the UK. One of the beauties is that, going forward, all that has already been done. Even if you no longer participate in Galileo, the things going on in it are not innovative. What you can do now is go back to the innovative roots and look at the next thing and where you want to go ahead and invest, grow and develop.

Q27 **The Chairman:** We are coming to the end of our session. We have had nearly an hour and I will give you a chance in a moment to say anything that you feel that we have not covered, but one question is nagging at my mind, given the sensitivity of security issues here and the possible adversarial difficulties that Dr Morin referred to briefly.

Collaboration with the United States does not exclude continued collaboration in some sense with Europe, but there is a sort of understanding there. We mentioned India, and there was brief mention of China. It is clear that one of the other regional systems that will be developed is the Chinese. We already have a little friction between the United Kingdom and the United States at the highest level over collaboration with China in a different but not unrelated field. Would collaboration with China in any of these areas prejudice collaboration with the United States?

Dr Jamie Morin: I would respectfully decline to state the policy of the United States, but I do believe that both the current US Administration, and the previous one in which I served, were quite concerned about a number of activities coming out of the People's Republic of China. The space sector is one of the areas of highest concern for the US Government. Multiple anti-satellite weapons tests and a demonstrated willingness to push or to go far beyond boundaries of what is acceptable in space raise significant concerns for the US, and I suspect will continue to do so.

I note, though, that the Cold War examples of space collaboration, not on the security side but on the exploration and scientific side, between the US, Europe and the Soviet Union suggests that space has a role in creating lanes or venues for co-operation in the midst of competition or even outright conflict. At present, the US has very limited co-operation with China, and we still have significant co-operation with the Russians, even as relations bump along.

If I was providing personal advice to the Government here it would be to be selective, and I would note that in a connected world the cybersecurity threats are very real. Critical technology is critical technology. So a degree of caution is warranted.

Q28 **The Chairman:** That reminds me of my very early youth. Harwell is a centre of space research, as Ms Galasso knows. When we went there it reminded me that in around 1970 it took about five passes for me to get to my office right in the centre of the Harwell complex. But there was very much scientific collaboration there. I got into my office one morning and there was a babble of people speaking Russian. Russian scientists were there all the time, and this was at the height of the Cold War. However, scientific collaboration does sometimes cause security concerns, and your delicate reply to my question indicates that we need to be aware of them.

Are there any other areas that we have not touched on that you think we should take into account and focus on, particularly if this Committee or its successor Committee decides to look at post-Brexit space activity?

Dr Jamie Morin: I will let my colleagues go first, since I have rather monopolised the conversation.

Gina Galasso: I have been spending quite a bit of time in the UK, and a common recurring theme that seems to come up is the lack of suitably qualified, experienced personnel in regards to space. Part of that is not necessarily in industry; it is also about making sure that the people in government channels who are interested in space, learning more about space and leveraging and growing space have enough knowledge of space so that they can go ahead and work better with industry. That has been brought up by the MoD and the UK Space Agency and is a really common theme that you may want to look at and address.

Robert Samuel Wilson: Gina's point is very important for the specific question, but another important takeaway from our paper is that while

the pursuit of an independent global satellite system may be the result of Brexit, it is not an inevitability of Brexit. The UK has a lot of options that raise really important questions and considerations for UK space leadership.

Dr Jamie Morin: I would just close by suggesting that the opportunities in space right now are very large. What humanity can accomplish in space is the intersection between three constraints. One is what is technically feasible. One is what is economically viable, which in the space sector often means, "What can I convince a Government to pay for?", but is increasingly also, "What can I sell to the public?" The third is, "What is policy-acceptable?" Space is, by treaty, an area where Governments have to license all activity and are responsible for it.

Those three constraints today are all-changing and all-moving. Technological feasibility is expanding at a pretty rapid pace and in unexpected and disruptive ways. New business models are emerging; new sources of capital are coming to the fore with different priorities; and Governments are looking again at their policies—"How sovereign is sovereign?", or, "How interdependent do I want to be?", but also, "How much control am I as a Government willing to relinquish to the private sector?"

All those three constraints are changing simultaneously. If you think of it as a Venn diagram, it is the union between those three that is possible. That union space, that "What is achievable?" space, is growing and moving. That is an enormous opportunity for the UK, the US and private players, and in many respects, although the space budget and space industry in the UK, or really anywhere in the world, is not a huge share of the national economy, it is an area of great ferment, energy and opportunity.

The comparatively blank slate which the UK is writing on post withdrawal from the Union is an opportunity as well as a challenge, because you can reconsider a great deal and build a de novo strategy to apply limited resources in novel ways. It is an exciting time and is why I am doing what I am doing right now—because there is so much excitement and energy in this area of human endeavour—and when so much is changing it is an opportunity to make a difference.

So it is good that the Committee is engaged on these issues and looking at them in the broader context. We certainly look forward to continued collaboration with the Government here and with the Committee.

The Chairman: Thank you very much, and thank you very much for your time. Unless my colleagues have any further points that they wish to raise, that concludes the session.